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Integrated Water Resources Management in Peru

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Abstract

Peru is a country with a strategic location for water resources, however, like many other countries, it is facing water supply and demand problems due to demographic densification growth, and pollution problems due to agricultural and industrial usage. In order to address these problems, integrated water resource management approach has been introduced. It includes the coordinated development, management and policies of water resource usage towards environmental protection, conservation and sustainability. However, this approach has not been fully developed within the Peruvian water management and policies structure. Due to Peru's complex social, economic, geographic and multicultural aspects, there are many things to consider when managing water resources and making effective policies. This paper shows how integrated water resources management approach should be developed and implemented in Peru, the importance of a holistic coordinated framework, and how environmental technologies and informatics are needed for addressing environmental problems in the Peruvian aquatic ecosystem.

Keywords: Aquatic ecosystem; Environmental policies; Environmental informatics; Integrated water resources management; Peru; Water law 29338.

1. Introduction to Peru

Peru is located on the western side of central South America. Its borders are the Pacific Ocean to the west with an extension of 200 miles, Ecuador and Colombia to the north, Brazil to the east and Bolivia and Chile to the south. Ecuador, Colombia, Bolivia and Peru form the Comunidad Andina de Naciones (CAN, Andes Community of Nations). The population is 29,132,013 people [1], the total area is 1,285,216 km2 and it is divided in three natural regions: la costa (the coast) with an area of approximately 11% of the country, la sierra (the mountains) containing of the Andes mountain range and accounting for 27% of the country's land area, and la selva (the jungle) which covers the majority 62% of the country. Peru has twenty-four departments and one constitutional province.

From the time that the Spanish first began colonizing Peru, people from all over the world have emigrated and settled in the country. The first Spanish conquerors brought African slaves and most of them have remained in Peru.

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Little by little other people moved to live in the country, from Europe, Asia, North America, Central America, South America, the Middle East, Africa and Oceana. The result is a multicultural and multiracial population living in a diverse geographical country.

Peru has a strategic location for water resources. Its territory includes the Pacific Ocean coast; the origin of the Amazon River, the longest river on the world; and 71% of the tropical glaciers in South America. 25% of the aquatic ecosystems are in the Amazon region and its basins represent 5% of the world's fresh water. Because of the availability of superficial, ground and atmospheric water, Peru has a large water supply accounting for 4.6% of the volume of the world's run-off [2].

However, the water supply is not equally distributed amongst the population. More people live in the coastal region (17,232,069 almost 60% of the total population) than in the mountain (9,170,804 31%) or the jungle (2,729,140 9%) regions [3]. Nevertheless, the water supply correlation in these three regions is completely opposite in relation to the amount of people [4]. The water availability (million m3) and the water availability per capita (m3/person) are uneven, 40,870.97 and 2,938.00 in the coastal region; 367,838.69 and 37,196.79 in the mountain region; and 1,634,838.61 and 641,954.44 in the jungle region, respectively [5]. The most populated region has the lowest available water supply and the less populated has the highest available water supply. Therefore, since Lima, the capital, is located on the coast along with many other developed cities, the most developed region could have the most serious water supply problem.

Even with this uneven distribution of population and water supply, people constantly move to the coast. As a result of the increasing population density, more physical domestic drainage problems (i.e. broken sewage pipes) have been detected. People are asking for better quality and quantity of drainage constructions and connections. To make matters worse, 86% of domestic sewage is not treated [6] and flows into the sea.

Peru can be divided into three slopes: Pacific (from the Pacific Ocean to the west), Atlantic (from the Atlantic Ocean to the north) and Titicaca (from Lake Titicaca to the south). Table1 shows information related to the geographic situation, the data of water resources according to the three slopes (— indicates data is not available) and their relations with the amount of people who live in each slope.

Table 1. Water supply to the population by slopes [1]

Slope	Extension (km^2)	Number of basins	Total of hydric resources (millions m^3)	Superficial water (millions m^3)	Ground Water (millions m^3)	Water supply (% of the total population)	Distributed population (% of the total population)
Total	1,285,216	106	2,045,609	2,042,870	2,739	100	100
Pacific	279,690	53	37,030	34,291	2,739	1.69	60.4
Atlantic	956,751	44	1,998,405	1,998,405	—	97.81	34.8
Titicaca	48,775	9	10,174	10,174	—	0.5	4.8

[1] Adapted from [7]; [8].

In order to address the uneven distribution of water supply and demand on the slopes, some water is either transferred from the Atlantic to the Pacific and Titicaca slopes by water diversions or is kept inside warehouses. It is important to understand that this uneven distribution not only refers to water supply for domestic use including consumption, hygienic and drainage, it also refers to other kinds of water use. Therefore, in the Pacific slope, the percentage of water supply is much lower than in the Atlantic because of its higher population and because of their higher amount of water use for agriculture, industries, domestic demand, mining and livestock. In general, the major water demand in all three slopes is for the agricultural sector, accounting for 86%, 84%, and 68%, respectively [9].

The Atlantic is the biggest slope and has the highest total amount of water resources. However, since also is the biggest area for agriculture, water is wasted by this sector. Particularly in some places in the Andes, because of the

traditions and the geography, gravity irrigation is used. For the locals this type is more convenient since gravity feed systems need minimal pressure to operate. Thus, a high percentage of this water goes to the ground.

Because of insufficient technology, there is not enough data to determine the amount of ground water in the Atlantic and Titicaca slopes. Even though the Atlantic slope has the highest total amount of water resources, this total does not include the ground water. Therefore, because the ground water's capacities and potentials are still unknown, it has still not been fully utilized. Also, because the amount of pollution is unknown, the impact through ground connections with the other slopes is still unclear.

2. Water Resources Management

Since the industrial revolution, human activities have been directly affecting the environment causing rapid change. In order to address the high demand that demographic densification puts on water resources and to control contamination, in the last few decades a new concept has arisen known as integrated water resources management (IWRM). IWRM has been developed for many years and it has been mentioned in many international forums. However, the term 'integrated' was formally added into the concept after the Dublin and Rio Summits. According to the Technical Committee of the Global Water Partnership, IWRM is a process that promotes the coordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems. To complement this definition, the United Nations Environmental Program UNEP adds, IWRM is necessary to address increasing water scarcity and pollution. Methods include water conservation and reuse, water harvesting, and waste management. An appropriate mix of legislation, pricing policies and enforcement measures is essential to optimize water conservation and protection.

Water management decisions not only implicate technological, scientific, administrative, economic, and political aspects, but also implicate social aspects (i.e. human attitude towards water use). Because water is our most important natural resource, every person has the right of access to water. For instance, usually water is accessible and fees are not expensive. However, since people have the right of access to water, human attitude towards water use is associated with a short-term value [10]. Therefore, water wastage is common, such as citizens who waste tap water, farmers who over-water crops, and other people who pollute water without any penalty (i.e., pollution from up-stream to down-stream by mines and factories sewages). Even though problems caused by mining or agriculture run-off can originate far away from the coast, the pollution also affects the ocean. The natural environment of sea species has been changed and people have to stop fishing and doing recreational activities. As a result of many actions combined, eutrophication emerges, especially close to the estuaries. Therefore, a holistic and shared attitude of importance towards the use of water is needed. People need to understand that their actions have a large impact on water resources and an irresponsible use of water can have terrible consequences, such as health problems and affecting natural habitats, because of a change in the hydrological balance.

In case of the CAN, the IWRM approach has to include cultural values of communities towards resources, particularly concerning the idea of 'mother earth' (pachamama, in Quechua) and traditional land technologies cannot be changed immediately, since they have been used for many centuries in the Andes region. In Peru, because of the lack of forward-thinking policies, for many centuries the Andes farmers have suffered the most. Looking back on history, before Spanish people arrived to conquer Peru in 1532, the Inca's Empire was a hierarchy divided into three social classes: royalty, aristocracy and ayllu. The last class was made up of newly colonized people, servants, slaves and farmers. Farmers did not have any power to make decisions. After the Spanish conquered Peru, many of the indigenous people were forced to work in gold mines where many farmers worked under terrible circumstances and lost their lives. Since Peruvian independence from Spain was declared in 1821, many indigenous people, particularly farmers, claimed that either militarist, aristocratic or civil governors do not fully understand them and that national policies tend to unfairly exclude their cultural values, traditional land technologies and interests. Thus, local people do not recognized all the authorities or institutions in charge of water resources named by the government. Either they consider that the decisions were made from a centrally controlled government that excludes them or either they do not understand the authorities and institutions' functions and responsibilities.

3. Water Resources Policies

During 1980's Peru had to face many problems related to uncontrolled emissions of the metal mining sector. There were conflicting regulations and a lack of regulation compliance. Because of this situation, from 1990-1997 many regulations and laws were made in Peru in order to create institutions in charge of the recognition, protection and conservation of cultural heritage and natural resources [11]. Most of them were general except for the Ley Orgánica para el Aprovechamiento Sostenible de los Recursos Naturales 1997 (Organic Law for Sustainably Taking Advantage of the Natural Resources). This law's objectives were to promote and regulate the sustainable use of renewable and non-renewable natural resources by establishing a correct frame for investment promotion while procuring a dynamic balance between the economic growth, the conservation of the natural resources, the environment and the integral development of the people [12]. The two periods of the Alberto Fujimori government focused on opening Peru to foreign investment, promoting more industrial development and private participation. In fact, the last law explicitly mentions the goal of investment promotion. During this period the Peruvian economy increased considerably and since 1992, the mining industry has attracted more than USD 10,000 million in foreign and domestic investment representing almost 50% of total exports between 1990 and 2005 [13]. However, not all the national sectors were satisfied with this growth. Leaders and representatives of local people who live downstream from metal mines protested claiming that the mines' impact to the water and air were above the maximum level of pollution permitted [14]; [15]; [16].

While the next president, Alejandro Toledo, was in power, the Décimo Novena Política del Acuerdo Nacional 2002 (National Agreement of the Tenth Ninth Policy) was made. As a national agreement, its goals were to promote the basins management; stimulate the environmental investment and the technology transfer to generate cleaner and more competitive actions for the drains; and promote and constantly evaluate the efficient use of water avoiding the negative externalities [17]. In comparison with other national laws, this was more detailed, especially because it directly referred to basins management and the negative externalities as a consequence of an inefficient use of water. Nevertheless, new laws have been made to improve older ones and the populations who live downstream from metal mines continues to show their disagreement with their municipalities' and national decisions [18]. According to the local people policies give preferential treatment to mines, forgetting the people's rights for a healthy living condition and forgetting the rights for the farmers who need a large amount of fresh water for their land and animals.

Since water is considered the main natural resource for domestic, industrial and agricultural use, and initially two of the sectors involved, domestic and agricultural, disagreed with the regulations and laws made, in May 2009 a new water law was discussed. The discussion about the law included goals to protect and preserve the water a natural resource; to promote and regulate the sustainable use of water from users upstream. However, even though in March 2009 a representative of Defensoría del Pueblo (People's Defense) commented that the water law should give preferences to people's rights and the use of water resources should work towards sustainable use, instead of just industrial purposes, local people showed their disagreement because they still did not believe the new law would recognize these aspects [19]. In June 2009, representatives from Cajamarca complained that the Yanacocha mine kept polluting their air and water with lead, copper and iron [20]. In October 2009, people protested in the streets of several cities showing their disagreement with the discussion of the new water resources law, also called water law 2009. They claimed that if that water law becomes the formal national law, then the mines would unfairly be given more water usage rights than the Andes farmers and local people living downstream [21]; [22]; [23].

In general, the water law disagreements were based on the interpretation of the law document. People protested because they were concerned that by the force of law, the government could decide the priorities of using water and who will have the rights of using water sources. The 2nd article of the water law said that there is no private ownership of the water, but the 47th article mentioned that the national institution in charge has the ability to decide who can have the rights to the water by giving a water use license. For instance, people were afraid that the government would change the 2nd article and decided to give priorities to the mining sector instead of the agricultural or domestic sectors [24]. Also, people were worried that the Intendencia de Recursos Hídricos (Water Resources Administration), that was part of the ministry of agriculture, would not be named as the main institution in charge of water resources [25].

Because of many disturbances in the country, this year (2010) the government finally released the formal national water law after having many discussions with more farmers and public representatives in 2009 and the water resources legislative orders were accepted [26]. In March 2010, the new water resources law 29338 was formally passed into law. In order to maintain peace and stop the disturbances by unsatisfied sectors, some articles of the law were changed and some remained the same. For instance, it keeps the 2nd article and it mentions that usage rights

systems cannot be transferred (i.e., in case an institution decides to give its water usage rights to a company). It also includes innovative topics such as the establishment of Autoridad National de Agua (ANA, National Authority of Water) as the maximum authority in charge of technical-norm aspects of the national water resources management system with the participation of the ministry of environment; specifies more about the water usage licenses (i.e. in case of no payment it is possible to cancel a given license). Now the water management has to consider the management of basins, and the participation of public organizations such as locals and farmers as part of the director council of ANA.

Since countries in the CAN share similar geographic, cultural, social and economic conditions, water resources management has been considered in the Agenda Ambiental Andina (Andes Environmental Agency). As part of the agenda, a strategy of the IWRM recognizes 21 Acciones del Agua (21 Actions of the Water). It was made by experts and representatives based on the shared available knowledge and the shared interests of the CAN region [27]. However, the objectives are still general and there is a lack of indicators that can help to assess and monitor the coordination of actions of the Agenda.

4. New approach

Because rivers and oceans are connected, environmental problems like the runoff of chemical and organic waste from industries (i.e. mining) and domestic use, negatively affect aquatic ecosystems [28]. Therefore, water carrying capacity, supplied potential, and human impacts are all important factors to consider when making water management policies. IWRM approach should not only apply to regions and basins, but also slopes, watersheds and estuaries, as they are also part of aquatic ecosystems [29]. However, in Peru the IWRM of basins is a relatively new approach [30]; [31]. While it has not yet been fully implement or adapted in the whole country, it has been suggested as a wider and more efficient management (i.e., Mantaro basin in Junin, Huancavelica, Pasco and Ayacucho departments, introduced a new coordinated project to clean the water from mining, agricultural and domestic wastes) than departmental self-management (i.e., Mantaro Valley in Junin department, where many mines are located and also an important hydroelectric center).

In Peru IWRM approach has been mentioned by many institutions, nevertheless, either the concept or its importance has not been fully developed. Even though the study of aquatic ecosystems points to the fact that water resources are interconnected, people have not yet fully recognized the damage that their waste causes to nature (i.e., mining companies' mercury waste run-off that affects domestic water supply). Therefore, a shared knowledge of the national situation is needed for a more responsible and efficient use of water. People need to understand that their actions have consequences and that their waste affects the entire water system since the water resources are linked by precipitation and evapotranspiration (ET), superficial and ground interconnections.

In the past few decades, technology has not only served industrial and commercial purposes, but also environmentalist causes. The human quest for knowledge and information in order to address environmental problems has created the field of environmental informatics. Environmental informatics could be considered as a wider approach than environmental information since it is related to the scientific process [32]. The first approach not only includes the design, development, implementation and application of computer-based information systems such as data and modeling, but also includes information processing such as environmental impact assessment EIA in order to explore the physical, chemical or biological human impacts on the natural environment. Environmental informatics as an interdisciplinary field that involves a variety of information-technology-based measures between natural or artificial systems, in connection with environmental monitoring and impacts, should be considered for the purpose of addressing environmental problems. However, national environmental systems analysis has not yet been fully implemented by the institutions in charge of environmental issues. Since there is a lack of ground water data and almost no constant monitoring and assessment of human impacts on basins, slopes, watersheds and estuaries, therefore, environmental informatics approach has not yet been fully developed in Peru.

The development of technologies for environmental informatics is needed to find new indicators for more precise and realistic monitoring and assessment [33]. For the purpose of improving IWRM with regards to balancing water supply and demand, environmental informatics is important to find indicators that can help with cost-effective solutions. For example, modeling indicators can help us to understand the short-term and long-term dynamics of mining pollutant behavior in order to find out the casual effect and cost-benefit relationship for immediate national policy planning in Peru [34]. Geographic informatics system GIS, could be useful to follow the agricultural

chemical and organic waste run-off in the Atlantic slope and its consequences on the Pacific slope since they are part of the same aquatic ecosystem. Remote sensing RS can help us to find out if and how climate change in Peru is impacting the melting Andes glaciers and how to mitigate this problem.

5. Conclusions

By improving engineering technologies, physical problems can be addressed. In Peru, the agriculture sector has the highest priority for water resource usage, however, in general the sector still does not change its type of irrigation or implement new technologies in order to improve water management. Because of agriculture overwatering, the plants cannot absorb all the water; therefore, this type of gravity irrigation wastes more water. For this reason, experts recommend irrigation by drip [35]. Experts also recommend that new technologies should be implement for the purpose of reusing the water used by the domestic sector. Besides, because of the physical problems with drainage constructions and connections, more technology services are needed for improving their quality and quantity. In the case of the mining impacts, clean technologies are needed to mitigate their pollution waste and consequences [36].

Using appropriate informatics, unknown data regarding the total quantity and quality of the ground water can be discovered as well as its capacity and potential to supply the water demand. Environmental informatics needs to be more fully developed in Peru in order to more efficiently address environmental problems in the aquatic ecosystem and it must be adapted and implemented by the institutions in charge. Thus, the information has to be provided in a timely manner, as an accessible and comprehensible part of an informatics network.

Therefore, since environmental and health institutions that are involved with the environmental management and policy-making (ministers of environment, agriculture, construction and energy and mines; CAN representatives; universities; health and scientific research centers; public associations; and consultants) agree that the water resource management should involve the entire country [37]. Also, environmental management should be based on knowledge and understanding of the functions and capacities of natural resources in the Peruvian ecosystem in order to support human activities and demands [38]. The water management for domestic, industrial and agricultural usage has to be geographically, culturally, socially, economically integrated in order to follow the principles of IWRM equity, efficiency and sustainability. As for the political integration, environmental policies have to include these concepts and principles in local, regional and national policies. However, it is important to delimitate rights and clearly define the responsibilities and functions of the authorities involved.

Environmental policies are needed in order to achieve sustainable use of natural resources and address environmental problems mainly caused by human activities. Even though the water resources law 29338 took a big step in improving water use, protection and conservation, its implementations might make little progress in a strong vertical system because of the bureaucratic process (i.e. legal, administrative and geographic boundaries). Therefore, either on the country level or the regional level, such as countries involved in a joint environmental project (i.e., CAN's project), a shared holistic and coordinated framework is needed. The basins, watersheds, slopes and estuaries management requires an operational framework and mechanisms for addressing ecological interconnectedness as well as upstream-downstream impacts as part of the same aquatic ecosystem. Their management and policy need a jurisdictional, multi-sector and multidisciplinary approach towards aquatic ecosystems. Besides, for the purpose of encouraging sustainable use, management and policies not only have to be based on administrative and political aspects, but also on geographic, social, economic, scientific and technological aspects. Therefore, representatives are motivated to participate in the management process, recognizing what institutions are in charge so that they trust and understand their well-defined, transparent functions in order to improve efficiency in IWRM implementation.

In case laws are only made to suit current government's interests, the shared holistic and coordinated framework has to remain over presidential periods. Particularly in some corrupt countries, decisions are made through centralized national laws only benefiting the capital and richer cities; in these cases the state forgets the poorest. Therefore, national laws have to remain as state's laws and not presidents' or political parties' laws. For the correct implementation of IWRM of the aquatic ecosystems, an improvement in the governance is needed. It is necessary to improve the government capacity for establishing accessible technologies and efficient management and effective policies through recognized institutions that involve transparent long-term processes and activities leading towards sustainability. Transparent governance is needed to take advantage of the benefits of natural resources and to avoid problems related to the water stress, including population growth, urbanization and industrialization, depletion of

aquifers, pollution, and climate change [39]; [40]. To be prepared for climate change, technologies and policies have to work towards the anticipation, mitigation and adapt decisions for its impacts [41].

For the purpose of improving governance and avoiding disturbances, disagreements and protests about the water management policies, representatives from the sectors involved should participate in local, municipal, provincial, regional and national meetings and discussions [42]. People should recognize that even though water is our most important resource and it is everybody's right to use it, a change in the hydrological balance is everybody's responsibility, not only the government's, and we are all facing the consequences of climate change. Thus, the water demand can be met more efficiently through a holistic understanding of the water usage by the sectors involved.

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